CLAIMS

1. A method for filling recessed micro-structures at a surface of a semiconductor workpiece with copper metallization comprising the steps of:

depositing a copper layer into the micro-structures with a process generating copper grains that are sufficiently small so as to substantially fill the recessed microstructures;

subjecting the deposited copper to an annealing process at a temperature below about 100 degrees Celsius.

2. A method as claimed in claim 1 wherein the copper is deposited using an electroplating process.

3. A method as claimed in claim 1 wherein an electroplating waveform is used, at least in part, to ensure sufficiently small copper grain size.

4. A method as claimed in claim 1 wherein an electroplating solution additive is used, at least in part, to ensure sufficiently small copper grain size.

5. A method as claimed in claim 1 wherein the annealing process is carried out at ambient room temperature.

6. A method as claimed in claim 1 wherein the annealing process comprises subjecting the workpiece to a controlled temperature gradient in which the temperature decreases along a cross-section of the workpiece in a direction that is opposite to the direction of formation of the copper during its deposition.

7. A method for filling recessed micro-structures at a surface of a semiconductor workpiece with metallization comprising the steps of:

depositing a metal layer into the micro-structures with a process generating copper grains that are sufficiently small so as to substantially fill the recessed microstructures;

subjecting the deposited metal to an annealing process at a temperature below about 100 degrees Celsius.

8. A method as claimed in claim 7 wherein the metal is deposited using an electroplating process.

9. A method as claimed in claim 7 wherein an electroplating waveform is used, at least in part, to ensure sufficiently small metal grain size.

10. A method as claimed in claim 7 wherein an electroplating solution additive is used, at least in part, to ensure sufficiently small metal grain size.

11. A method as claimed in claim 7 wherein the annealing process is carried out at ambient room temperature.

12. A method as claimed in claim 7 wherein the annealing process comprises subjecting the workpiece to a controlled temperature gradient in which the temperature decreases along a cross-section of the workpiece in a direction that is opposite to the direction of formation of the copper during its deposition.

13. A method for filling recessed micro-structures at a surface of a semiconductor workpiece with copper metallization comprising the steps of:

providing a semiconductor workpiece with a feature that is to be connected with copper metallization;

applying at least one dielectric layer over a surface of the semiconductor workpiece including the feature;

providing recessed micro-structures in the at least one dielectric layer;

preparing a surface of the workpiece including the recessed micro-structures with a seed layer for subsequent electrochemical copper deposition;

electrochemically depositing a copper layer to the surface of the workpiece to substantially fill the recessed micro-structures;

allowing the electrochemically deposited copper layer to self-anneal for a predetermined period of time at ambient room temperature;

removing copper metallization from the surface of the workpiece except from the recessed microstructures, said removing step occurring after the predetermined period of time has elapsed.

14. A method as claimed in claim 13 wherein the predetermined period is greater than about 20 hours.

15. A method as claimed in claim 13 wherein the step of preparing a surface of the workpiece comprises:

applying at least one barrier layer over the dielectric layer; and

applying a seed layer over the barrier layer.

16. A method as claimed in claim 15 wherein the step of applying the seed layer is defined by applying the seed layer using a chemical vapor deposition process.

17. A method as claimed in claim 15 wherein the step of applying the seed layer is defined by applying the seed layer using a physical vapor deposition process.

18. A method as claimed in claim 13 wherein the step of preparing a surface of the workpiece comprises:

applying at least one adhesion layer over the dielectric layer; and

applying a seed layer over the adhesion layer.

19. A method as claimed in claim 13 wherein the step of removing the copper metallization is defined by removing the copper metallization using a chemical mechanical polish technique.

20. A method for filling recessed micro-structures at a surface of a semiconductor workpiece with copper metallization comprising the steps of:

providing a semiconductor workpiece with a feature that is to be connected with copper metallization;

applying at least one dielectric layer over a surface of the semiconductor workpiece including the feature;

providing recessed micro-structures in the at least one dielectric layer;

preparing a surface of the workpiece including the recessed micro-structures with a seed layer for subsequent electrochemical copper deposition;

electrochemically depositing a copper layer to the surface of the workpiece to substantially fill the recessed micro-structures;

removing copper metallization from the surface of the workpiece except from the recessed micro-structures;

allowing the electrochemically deposited copper layer to self-anneal at ambient room temperature without subjecting the workpiece to a separate and distinct elevated temperature annealing process.

21. A method as claimed in claim 20 wherein the step of preparing a surface of the workpiece comprises:

applying at least one adhesion layer over the dielectric layer; and

applying a seed layer over the adhesion layer.

22. A method as claimed in claim 20 wherein the step of preparing a surface of the workpiece comprises:

applying at least one barrier layer over the dielectric layer; and

applying a seed layer over the barrier layer.

23. A method as claimed in claim 22 wherein the step of applying the seed layer is defined by applying the seed layer using a chemical vapor deposition process.

24. A method as claimed in claim 22 wherein the step of applying the seed layer is defined by applying the seed layer using a physical vapor deposition process.

25. A method as claimed in claim 20 wherein the step of removing the copper metallization is defined by removing the copper metallization using a chemical mechanical polish technique.

26. A method for filling recessed micro-structures at a surface of a semiconductor workpiece with copper metallization comprising the steps of:

providing a semiconductor workpiece with a feature that is to be connected with copper metallization;

applying at least one dielectric layer over a surface of the semiconductor workpiece including the feature;

providing recessed micro-structures in the at least one dielectric layer;

preparing a surface of the workpiece, including the recessed micro-structures, with a seed layer for subsequent electrochemical copper deposition;

electrochemically depositing a copper layer to the surface of the workpiece to substantially fill the recessed micro-structures;

subjecting the electrochemically deposited copper layer to an annealing process at a temperature below about 100 degrees Celsius.

27. A method as claimed in claim 26 wherein the step of preparing a surface of the workpiece comprises:

applying at least one adhesion layer over the dielectric layer; and

applying a seed layer over the adhesion layer.

28. A method as claimed in claim 26 wherein the step of preparing a surface of the workpiece comprises:

applying at least one barrier layer over the dielectric layer; and

applying a seed layer over the barrier layer.

29. A method as claimed in claim 28 wherein the step of applying the seed layer is defined by applying the seed layer using a chemical vapor deposition process.

30. A method as claimed in claim 28 wherein the step of applying the seed layer is defined by applying the seed layer using a physical vapor deposition process.

31. A method as claimed in claim 26 wherein the step of removing the copper metallization is defined by removing the copper metallization using a chemical mechanical polish technique.

32. A method as claimed in claim 26 wherein the annealing process comprises subjecting the workpiece to a controlled temperature gradient in which the temperature decreases along a cross-section of the

workpiece in a direction that is opposite to the direction of formation of the copper during its deposition.

33. A method for filling recessed micro-structures at a surface of a semiconductor workpiece with copper metallization comprising the steps of:

providing a semiconductor workpiece with a feature that is to be connected with copper metallization;

applying at least one low-K dielectric layer over a surface of the semiconductor workpiece including the feature;

providing recessed micro-structures in the at least one low-K dielectric layer;

preparing a surface of the workpiece, including the recessed micro-structures, with a seed layer for subsequent electrochemical copper deposition;

electrochemically depositing a copper layer to the surface of the workpiece to substantially fill the recessed micro-structures;

subjecting the electrochemically deposited copper layer to an annealing process at a temperature below which the low-K dielectric layer substantially degrades.

34. A method as claimed in claim 33 wherein the annealing process comprises subjecting the workpiece to a controlled temperature gradient

in which the temperature decreases along a cross-section of the workpiece in a direction that is opposite to the direction of formation of the copper during its deposition .

35. A method as claimed in claim 33 wherein the annealing step takes place at a temperature corresponding to a baking temperature of the low-K dielectric.

36. A method for reducing voids in a metal material that has been electrolytically deposited into recessed micro-structures of a microelectronic workpiece comprising the step of subjecting the workpiece to an annealing process at a temperature that is at or below about 250 degrees Celsius.

37. A method as set forth in claim 36 wherein the metal material comprises copper.

38. A method as set forth in claim 36 wherein the annealing process comprises subjecting the workpiece to a controlled temperature gradient in which the temperature decreases along a cross-section of the

workpiece in a direction that is opposite to the direction of formation of the metal material during its deposition .

39. A method as set forth in claim 37 wherein the annealing process comprises subjecting the workpiece to a controlled temperature gradient in which the temperature decreases along a cross-section of the workpiece in a direction that is opposite to the direction of the formation of the deposited metal material.

40. A method for reducing voids in a metal material that has been electrolytically deposited into recessed micro-structures of a microelectronic workpiece comprising the step of subjecting the workpiece to an annealing process in which the workpiece is subject to a controlled temperature gradient in which the temperature decreases along a cross-section of the workpiece in a direction that is opposite to the direction of the formation of the deposited metal material.

41. An apparatus for use in applying metallization in recessed micro-structures of a microelectronic workpiece comprising:

at least one deposition station for depositing a conductive material into at least the recessed micro-structures of the microelectronic workpiece;

at least one annealing station for subjecting the microelectronic workpiece to an annealing temperature that is at or below about 250 degrees Celsius.

42. An apparatus as set forth in claim 41 wherein the at least one deposition station electrolytically deposits the conductive material and wherein the conductive material comprises copper.

43. An apparatus as set forth in claim 41 and further comprising a robotic workpiece handling system for transferring microelectronic workpieces to and from the at least one deposition station and to or from the least one annealing station.

44. An apparatus as set forth in claim 42 wherein the workpiece handling system comprises:

a first robot arm disposed to transfer the microelectronic workpieces to and from the at least one deposition station;

a second robot arm disposed to transfer the microelectronic workpieces to and from the at least one annealing station.

45. An apparatus as set forth in claim 41 wherein the at least one annealing station operates to subject the workpiece to a controlled temperature

gradient in which the temperature decreases along a cross-section of the workpiece in a direction that is opposite to the direction in which the metal material is formed at the at least one deposition station.

46. An apparatus as set forth in claim 42 wherein the at least one annealing station operates to subject the workpiece to a controlled temperature gradient in which the temperature decreases along a cross-section of the workpiece in a direction that is opposite to the direction in which the metal material is formed at the at least one deposition station.

47. An apparatus as set forth in claim 41 wherein the at least one annealing station comprises:

a heated generator proximate a first side of the workpiece to heat the first side of the workpiece; and

a fluid flow system directing a flow of cooling fluid at a second side of the workpiece, opposite the first side, to thereby generate a temperature gradient between the first and second sides of the workpiece.

48. An apparatus as set forth in claim 47 wherein the fluid flow system directs a cooling gas across the second surface of the workpiece.

49. An apparatus as set forth in claim 47 wherein the fluid flow system comprises:

a cooling member proximate a second side of the microelectronic workpiece for cooling the second side of the workpiece ; and

at least one channel associated with the cooling member for directing a flow of cooling gas therethrough to cool the cooling member.

50. An apparatus as set forth in claim 47 wherein the heat generator comprises a hot plate contacting the first side of the microelectronic workpiece.

51. An apparatus as set forth in claim 47 wherein the heat generator comprises an ultraviolet radiation source disposed to direct ultraviolet radiation toward the first side of the microelectronic workpiece.

52. An apparatus as set forth in claim 47 wherein the heat generator comprises radiative heat source disposed at the first side of the microelectronic workpiece.

53. An apparatus as set forth in claim 47 wherein the heat generator comprises a laser source disposed to selectively direct laser radiation at selective portions of the first side of the microelectronic workpiece.

54. An apparatus as set forth in claim 41 and further comprising a programmable control system connected to control the magnitude of the temperature gradient.

55. An apparatus for use fabricating metallization in recessed micro-structures of a microelectronic workpiece comprising:

at least one deposition station for depositing a conductive material into at least the recessed micro-structures of the microelectronic workpiece;

at least one annealing station for subjecting the microelectronic workpiece to an annealing process in which the workpiece is subject to a controlled temperature gradient.

56. An apparatus as claimed in claim 55 in which the temperature gradient is such that the temperature decreases along a cross-section of the workpiece in a direction that is opposite to the direction of the formation of the deposited metal material.

57. An apparatus as set forth in claim 55 wherein the at least one deposition station electrolytically deposits the conductive material and wherein the conductive material comprises copper.

58. An apparatus as set forth in claim 55 and further comprising a robotic workpiece handling system for transferring microelectronic workpieces to and from the at least one deposition station and to or from the least one annealing station.

59. An apparatus as set forth in claim 58 wherein the workpiece handling system comprises:

a first robot arm disposed to transfer the microelectronic workpieces to and from the at least one deposition station;

a second robot arm disposed to transfer the microelectronic workpieces to and from the at least one annealing station.

60. An apparatus as set forth in claim 55 wherein the at least one annealing station comprises:

a heated generator proximate a first side of the workpiece to heat the first side of the workpiece; and

a fluid flow system directing a flow of cooling fluid at a second side of the workpiece, opposite the first side, to thereby generate a temperature gradient between the first and second sides of the workpiece.

61. An apparatus as set forth in claim 55 wherein the fluid flow system directs a cooling gas across the second surface of the workpiece.

62. An apparatus as set forth in claim 55 wherein the fluid flow system comprises:

a cooling member proximate a second side of the microelectronic workpiece for cooling the second side of the workpiece ; and

at least one channel associated with the cooling member for directing a flow of cooling gas therethrough to cool the cooling member.

63. An apparatus as set forth in claim 55 wherein the heat generator comprises a hot plate contacting the first side of the microelectronic workpiece.

64. An apparatus as set forth in claim 55 wherein the heat generator comprises an ultraviolet radiation source disposed to direct ultraviolet radiation toward the first side of the microelectronic workpiece.

65. An apparatus as set forth in claim 55 wherein the heat generator comprises radiative heat source disposed at the first side of the microelectronic workpiece.

66. An apparatus as set forth in claim 55 wherein the heat generator comprises a laser source disposed to selectively direct laser radiation at selective portions of the first side of the microelectronic workpiece.

67. An apparatus as set forth in claim 55 and further comprising a programmable control system connected to control the magnitude of the temperature gradient.